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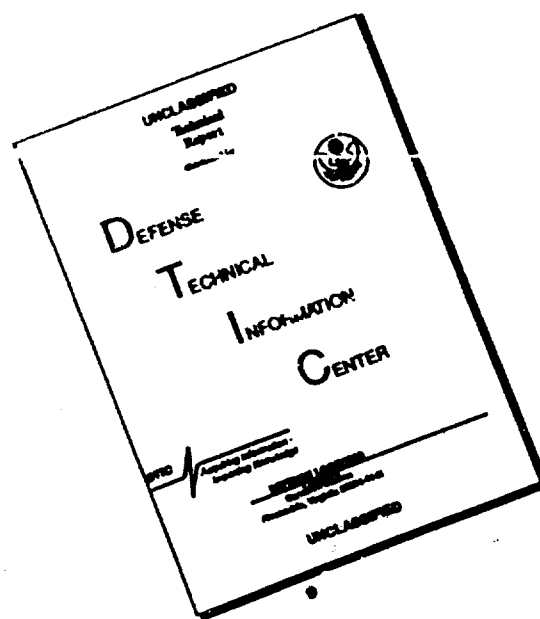
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13. ABSTRACT *(Maximum 200 words)*

The researchers undertook an examination of many of the mathematical issues that are well understood in the case of the medical application of these tomographic ideas (i.e. x-ray scanners) but have not yet been explored in the arena of radar imaging. Among the issues concentrated on were: (1) an understanding of the way in which data might be collected in radar, (2) the proper interpretation of these data as "projections of a two dimensional distribution in range-Doppler space", (3) a careful study of the effect that "ellipsoidal integrals" or even simpler "strip integrals" will have on an algorithm that is supposed to work with "line integrals", (4) a study of the effect that an increase of "lateral sampling per one dimensional projection" will have on the final reconstructions. This issue is well understood in the medical application and it serves to determine the number of detectors to be used, but has to be reexamined and reinterpreted in the radar context, (5) a study of the "competing methods" to obtain range-Doppler images. These include Synthetic Aperture Radar, and are based on the relative mention of the object vis-a-vis the radar.

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Prepared By: F. Alberto Grunbaum

FINAL REPORT

for

Air Force (DARPA) Contract # F49620-89-C-0107

Period of Contract: 9/1/89-10/31/92

Amount of Contract: $355,643

Title: Tomographic Mathematical Ideas Applied to Radar Detection

During the initial part of the joint effort with Marv
Bernfeld, formerly with Raytheon Co.,
I made an effort to get a better understanding of radar
signal processing in its standard form and in the new
modality that Bernfeld and Grunbaum have proposed.

The main difference between our novel approach and other applications
of "tomographic ideas" to radar, like SAR is that we do not need any
relative motion. Our "diversity of views" is produced by varying
the "chirp rate" of the pulse.

In a certain sense our approach is to SAR what Magnetic Resonance
Imaging is to standard X-Ray Imaging with a movable X-ray tube.
In the case of MRI the diversity of views is obtained by
ELECTRONICALLY altering the alignment of the gradient magnetic
field. Of course in the medical case there are all sort of other
differences between X-ray and MRI physical processes but
the switch away from mechanical motion is similar to the
one introduced in the Bernfeld/Grunbaum proposal.

I have undertaken an examination of many of the mathematical
issues that are well understood in the case of the medical
application of these tomographic ideas (i.e. X-ray scanners)
but have not yet been explored in the arena of radar
imaging.

Among these issues I concentrated mainly on

An understanding of the way in which data might be collected
in radar.

The proper interpretation of these data as "projections
of a two dimensional distribution in range-Doppler space".

A careful study of the effect that "ellipsoidal integrals" or even simpler "strip integrals" will have on an algorithm that is supposed to work with "line integrals".

A study of the effect that an increase of "lateral sampling per one dimensional projection" will have on the final reconstructions.This issue is well understood in the medical application and it serves to determine the number of detectors to be used, but has to be reexamined and reinterpreted in the radar context.

A study of the "competing methods" to obtain range-Doppler images.These include Synthetic Aperture Radar, and are based on the relative motion of the object vis-a vis the radar.

Partly on my own, and partly as the result of discussions with Bernfeld I have spent a good deal of time in the problem of "limited range of views" during the latter part of the period covered by the contract.

This problem arises when one does have access to the full 180 degrees range of views.
In the medical case this problem is only of practical interest in cases like the Imatron imager which produces a two dimensional picture every .04 seconds. In most scanners however one gets a "full view around the patient".

In the case of range-Doppler radar imaging using tomographic techniques as proposed by Bernfeld-Grunbaum different views are obtained by changing the "chirp rate" in the wave form that is sent to the target.Since there are practical limitations on what chirp rates can be produced we will always have to deal with the problem of "limited views".

I have started considering alternatives to the usual filtered backprojection algoritms that are used in the case of a full range of views.Although this method has been adapted appropriately to the case of a "limited range of views" and its optimal design has been thoroughly studied in a paper of mine (and M. Davison) I feel that it may be necessary to do away altogether with such algorithms in a case of very little available data as one may encounter in certain applications contemplated for this new way of doing radar imaging.

The effect of "streaking" and other annoying features on the reconstructed image have been analyzed.I have also undertaken a rather ambitious study that aims at deciding an "optimal choice " of "chirping rates" to be used with a certain range of implementable rates.A result of this study is that

"equispacing the rates" is not necessarily the best strategy.

This study points to the need for a small scale experimental
setup that would allow us to validate some of this "analytical
predictions".For instance the study of an optimal choice for the
chirping rates is based on a most pesimistic assumption on the
nature of the noise in the system, and is essentially a singular
value decomposition and condition number study.
It is entirely plausible that the nature of the noise in the
system would make a different "sampling scheme" preferable
to the one deduced analytically.Only a good series of experiments
would clarify this, AND MANY OTHER points.

We intend to find a good place to try to start validating
some of the analytical predictions that we have made so far.
At this point, the AirForce Rome Laboratory Surveillance
Facility at Griffiss AF Basis seems to offer the best fit to our
program.